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How does visual context influence recognition of facial emotion in people with traumatic brain injury?

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ABSTRACT

Objective: The current study assessed recognition of facial emotional stimuli following traumatic brain injury (TBI) and examined whether performance may be influenced by emotional visual scenes.
Methods: Thirty-five patients with moderate-to-severe TBI and 55 matched controls completed the novel Angers Facial Expression in Context Task (AFECT), designed to examine recognition of facial expressions of basic emotions in both congruent and incongruent emotional visual contexts.
Results: In comparison with non-brain damaged adults, patients with TBI performed more poorly and slowly on both contextual conditions (congruent vs. incongruent) of the AFECT.
Conclusion: Taken together, these results raise the possibility that adults with TBI may not fully benefit from supportive contextual cues. Also, they stress the importance of using emotional stimuli that better capture affect processing in real-world contexts and open up new avenues to better understand negative social outcomes in patients with TBI.

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Introduction

Breakdowns in social functioning are common in individuals with moderate-to-severe traumatic brain injury (TBI) (1–5) and are predictors of overall outcome (6,7). Although there are likely to be several factors underlying reduced psychosocial functioning following TBI, poor ability to decode isolated emotional facial expressions has been strongly associated with negative social outcomes, such as poor social integration (8,9) and socially inappropriate behaviours (10–12). Furthermore, a patient with a known history of emotional and social behaviour problems following TBI showed impairments on tests assessing interpretation of social situations (13). As context is often necessary for accurately understanding affective cues in everyday environment (14,15), investigating facial emotion recognition within situational contexts may help us to better discern social skill difficulties following TBI.

Over the past decades, emotion recognition following TBI has received an increasing amount of attention and a recent meta-analysis estimated that between 13% and 39% of individuals in the chronic phase of a moderate-to-severe TBI are significantly impaired at recognizing facial affect (16). Overwhelmingly, these impairments have been demonstrated with context-free emotional faces (1,2,8,11,17–33). Despite the importance of these studies, one rarely encounters faces in an isolated fashion. Facial expressions are generally embedded in a rich and informative context (for reviews see (14,15,34,35)). Thus, examining how individuals with TBI recognize facial emotion within situational contexts may better capture the real-world processes underlying their impairments. Indeed, context is important to consider because context-free faces are inherently ambiguous (36) and several studies (14,15,34,35,37) have emphasized the influence of context on facial expression categorization, providing support for the idea that ‘all in all, one wonders about the significance of studies of the recognition of “facial expressions of emotions”, in isolation of context’ ((38), p.638). Moreover, in number real-life situations, facial expression just looks too ambiguous to decide what emotion a person is displaying. As a consequence, context may be helpful to make correct inferences on the person’s emotional state and to guide our own behaviour during social interactions. Recent reviews (14,35) have suggested that contextual influences on facial expression recognition may arise from different sources such as within-expresser features (affective prosody, body posture, eye gaze, facial dynamics) and external-expresser cues (other faces, visual scenes, verbal descriptions). To date, how external-expresser cues or, more precisely, how the visual scenes influence facial expression perception in patients with TBI has been relatively unexplored.

To our knowledge, only Turkstra et al.’s study (39) has yet examined the role of visual scenes on affect recognition in individuals with TBI. Five patients were asked to label emotions from faces presented in a context-free condition and in photographs of everyday people embedded in real-life scenarios that were emotionally meaningful and evocative. Interestingly, individuals with TBI produced more multiple emotional words to describe facial expressions in context and in isolation than undergraduate students. This pattern of

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results would suggest that individuals with TBI may have subtle discrepancies in recognizing facial emotions when they are embedded in situational contexts.

A growing body of literature has investigated whether the emotional visual scene context may influence the processing of facial expressions in healthy participants (36,40–46). By superimposing faces on top of a scenic background, a clear congruency effect has been demonstrated such that categorization of facial expressions was faster (45) and more accurate (42) in congruent scene than in incongruent visual condition. In the same vein, several studies have highlighted that incongruent visual context could dramatically shift the recognition of facial emotion (36,40,42–45) even for categorization of neutral facial expression (47,48). Investigating the neural processing of two facial expressions (fearful and happy) exposed either after negatively or positively valenced visual context, Mobbs et al. (48) have pointed out that congruent conditions (fearful face-negative context or happy face-positive context) revealed mainly increased activity in the right amygdala, the temporal pole, the insula as well as in the left hippocampus whereas incongruent conditions (fearful face-positive context or happy face-negative context) were associated with increased activity in the right ventral prefrontal cortex, the amygdala and the left insula. Taken together, these studies clearly demonstrate that cognitive and neural processes involved in recognition of facial expressions in congruent context and those involved in incongruent context may be different.

The current study was specifically designed to assess how visual scene cues modulate facial affect interpretation in patients with moderate-to-severe TBI and normal controls. To this end, the Angers Facial Expression in Context Task (AFECT), a novel experimental paradigm that compares affect recognition of faces embedded into congruent and incongruent emotionally evocative visual scenes, has been designed. Pilot studies were carried out to ensure the two contextual conditions were of equal difficulty for healthy participants.

Consistent with previous literature, individuals with moderate-to-severe TBI were predicted to exhibit reduced facial expression recognition ability and to be slowed down across all conditions. Given evidence that unexpectedness of the incongruent condition results in more cognitive effort (42,45) and involves prefrontal cortex (48), we hypothesized that patients with TBI would be more affected by incongruent condition in comparison with congruent condition (both for response-times (RTs) and accuracy).

Methods and Materials

Participants

Thirty-five right-handed adults with moderate-to-severe TBI (30 male, 5 female) as well as 55 right-handed normal control (NC) participants (39 male, 16 female) were included. Previously their inclusion, they all gave informed consent in accordance with the Helsinki Declaration (1975), revised in 2008.

Patients were recruited through brain injury units in Angers and La Membrolle-sur-Choisille (France). TBI severity was assessed using the standard injury criteria (49), i.e. a Glasgow Coma Scale (GCS) score lower than 13 in the first 24 h, or a loss of consciousness (LoC) of 30 min or more, or post-traumatic amnesia (PTA) of 1 day or more and evidence of cortical or brainstem damage. GCS score was available only for 29 patients; all these scores were between 3 and 9, with a mean of 6.24 (SD = 2.05). For 14 patients, from whom the LoC data were available, the LoC duration mean was 21.7 days (SD = 18.5), with a range from 4 to 56 days. PTA data were available only for four patients with a range of 3–90 days. At the time of the study, clinical staff reported a lack of confusion for these participants. Following the classification (49), two patients were classified as having a moderate TBI and 33 had severe TBI. Seventeen patients were in the sub-acute phase (time since injury (TSI) <1 year), whereas the others were in the chronic stage post-injury. The TSI mean was 51.5 months (SD = 85.53) with a broad range from 2 months to 24 years. Participants with TBI were aged from 18 to 49 years (M age = 31.4 years; SD = 9.4) with an average of 11.7 years of education (SD = 2.7; range: 9–17 years).

Fifty-five NC participants were recruited from the general community and among patients' relatives. They were aged from 18 to 60 years (M age = 32.1 years; SD = 10.8) with an average of 12.2 years of education (SD = 2.1; range: 9–17 years). They were matched as closely as possible to the participants with TBI according to age (U = 945.5; Z = 0.13; p = 0.89), sex ($\chi^2(1)$ = 2.62, p = 0.11) and education level (U = 758; Z = 1.688, p = 0.10) (see Table 1).

For both groups, exclusion criteria were history of developmental or psychiatric disorders and also uncorrected vision impairments, communication disabilities (assessed by Boston Diagnostic of Aphasia Examination (BDAE) (50)), prosopagnosia (explored with Benton's Test of Facial Recognition (BTFR) (51)) and depression (measured by Beck Depression Inventory-II (BDI-II) (52)). A significant group difference for the depression score was observed (U = 272.5, Z = 3.90, p = 0.00009); however, a clinical depression characterized by a BDI-II score over 20 was not observed in participants with TBI such as in NC adults. In the same vein, the mean BTFR score of the adults with TBI was below to that of the NC participants (U = 12.5, Z = 4.46, p = 0.000001), but all performances were within the normal range. No group difference on BDAE accuracy was observed (U = 2.56, Z = 2.71, p > 0.01) and none of the patients or NC participants scored below cut-off.

Table 1. Demographics and measures of clinical functioning of TBI (n = 35) and normal control (NC) (n = 55) groups.

	TBI group		NC group		
	M (SD)	Range	M (M (SD)	Range	p
Sex	30 Male, 5 female		39 Male, 16 female		
Age	31.4 (9.4)	18–49	32.1 (10.8)	18–60	>0.01
Educational level (years)	11.7 (2.7)	9–17	12.2 (2.1)	9–17	>0.01
BDI-II (total score)	6.6 (5.5)	0–18	3.17 (2.4)	0–7	<0.0001
BTFR (total score)	39 (4.3)	33–41	47.1 (2.8)	41–51	<0.0001
BDAE (total score)	156.7 (6.2)	148–164	162.9 (0.6)	161–164	>0.01

M: mean; SD: standard deviation; BDI II: Beck Depression Inventory-II; BTFR: Benton's Test of Facial Recognition; BDAE: Boston Diagnostic of Aphasia Examination.

Measures and procedure

Emotional context and AFECT validation checks

In order to investigate facial expression of emotion in context, we had to construct the stimuli because no task currently exists. In this aim, the following procedure was used. First of all, 28 emotional scenarios were built specifically and rated by 20 undergraduate students. They were asked to judge the following emotions: anger, disgust, joy, fear, surprise, sadness or no emotion in each scenario. To do that, they used a 5-point likert-type scale, ranging from 1 'not at all' to 5 'very likely'. A scenario was attributed to an emotional category (anger, disgust, joy, fear, surprise, sadness or no emotion) if two criteria were respected: (1) to score higher to 3 in one emotional category and (2) to score lower to 3 in all other emotional categories. This first step of the selection process yielded 21 emotional scenarios. Scene images of the 21 scenarios depicting six emotional context (anger, disgust, joy, fear, surprise, sadness) as well as a neutral situation (three different scenarios per emotion) have been staged (for example, a woman was attacked with a knife by a man in an urban street). For each scenario, body pictures of Caucasian non-professional actors (four men and five women) expressing six facial emotions (anger, disgust, fear, happiness, sadness, surprise), as well as neutral state were photographed with a digital camera (Samsung NV7 OPS, 7.2 mega-pixels), while adopting a neutral posture. This display, designed to assess recognition of facial expressions embedded in an emotionally evocative visual scene, resulted in the creation of 147 face-emotional context stimuli (21 emotionally situations × 7 facial expressions). To validate the photographs, a sample of 60 healthy participants (26 male, 34 female; M age = 38.9 years; SD = 13.34; range: 20–60 years; 34 had attended university) was asked to recognize the facial emotion expressed by the central character. This recognition was operated in a forced-choice procedure by choosing one among seven emotion labels (anger, disgust, fear, happiness, sadness, surprise and neutral). The AFECT was built with stimuli from which a minimal achievement of 70% accuracy was reached.

Angers facial expression in context task

The AFECT was comprised of 30 grey-scale photographs, approximately 9 cm × 13 cm, displaying the following emotions: anger, disgust, fear, happiness, sadness, surprise and neutral state. All stimuli, taken from the validation study, were carefully controlled by having an equal number of positive and negative emotions as well as an equivalent number of male and female faces. The facial expression could be either congruent or incongruent with the emotional context (for example, in congruent condition, a scared woman (facial expression of fear) was attacked with a knife by a man in an urban street (context of fear) and in incongruent condition, a woman is angry (facial expression of anger) when her boyfriend makes his wedding proposal (context of happiness)). Sample for the two visual context conditions are shown in Figure 1.

Each visual context condition contained 15 items selected from among the stimuli of the validation study, such that the congruent and incongruent conditions were statistically equivalent in difficulty for the healthy subjects ($p > 0.10$).

AFECT procedure

Participants gave written informed consent to participate in the study in accordance with the Declaration of Helsinki (1975), revised in 2008. The AFECT was administered individually via a laptop computer, in a quiet room. Stimuli presentation and response input were coordinated using Media Control Function software (Digivox, Montreal). The task started with three practice trials (one in congruent condition and two in incongruent condition), in order to assure that participants understood the experimental task. After successfully performed the practice trials, 30 photographs were shown one by one. Photographs remained on the screen all the time the participant needed to identify the facial expression displayed.

All participants were requested to categorize each facial expression in a forced-choice procedure choosing one from among seven emotional labels listed just below each image

Congruent Condition   Incongruent Condition

Figure 1. Sample for the two visual context conditions.

(angry, disgust, fear, happiness, sadness, surprise and neutral). The presentation order of the different photographs was randomized across participants. Participants were asked to respond, by clicking on the appropriate label displayed under the image on the screen, as soon as they made their decision. Moreover, RT measures (in seconds), defined as the intervals between stimulus presentation onset and participant's response, were recorded.

Statistical analysis

The recognition accuracy was calculated by averaging the percentage of correct responses for each visual context condition in each group of participants. Also, analyses were conducted on mean RTs. RTs recorded from the correct trials were considered as outliers and discarded from the analysis when they exceeded $P_{75} \pm 2 \times (P_{75} - P_{25})$ where P_{25} and P_{75} denoting the 25th and 75th percentile computed over the set of correct trials for each visual context condition. This procedure was applied within each group of participants. Following these criteria, only a few trials were removed from the RT analyses (congruent condition: 1.52% and 1.21% for patients with TBI and NC participants, respectively; incongruent condition: 1.7% and 2.18% for patients with TBI and NC participants, respectively).

Normality condition was tested on all variables using a Kolmogorov–Smirnov test ($\alpha = 0.05$). Since both percentage of correct responses and RTs were not normally distributed (all $d > 0.17$; $p < 0.001$), a non-parametric approach was adopted. The factors were group (individuals with TBI vs. NC) and visual context conditions (congruent vs. incongruent). Group differences in facial expression recognition ability were assessed by Mann–Whitney *U* tests. To investigate effect of context congruency, Wilcoxon analyses were applied within each group. Effect size (r) for each significant Mann–Whitney *U* test and Wilcoxon test was also calculated ($r = |Z|/\sqrt{N}$).

To end up, Spearman rank-order correlations were calculated to determine the relationship between visual context conditions accuracy (congruent vs. incongruent), and to assess the relationships between visual context conditions accuracy and demographic variables (age, level of education).

All statistical analyses were carried out using Statistica 9.0 (StatSoft. Inc. Tulsa, OK, USA) and statistical significance was set at $p < 0.05$ for all analysis.

Results

Accuracy of facial expression recognition

To establish that both individuals with TBI and NC participants selected emotion labels for each facial expression at or above chance, goodness of fit chi square tests were used. Results indicated that patients with moderate-to-severe TBI and NC participants were not choosing emotions based on chance alone (all *p*-values < 0.05) in both congruent and incongruent conditions.

Mean percentage of correct responses in AFECT for groups (TBI, NC) across visual context conditions (congruent, incongruent) is shown in Figure 2. The prediction that individuals with TBI would exhibit reduced emotion recognition accuracy across all visual context conditions was supported. Analyses revealed that individuals with TBI were globally significantly less accurate than NC participants both when context is congruent with facial emotion ($U = 360$; $Z = 5.025$; $p < 0.000001$; $r = 0.53$) and when it is incongruent ($U = 338.5$; $Z = 5.18$; $p < 0.0000001$; $r = 0.55$). In order to investigate effect of context congruency on accuracy in both

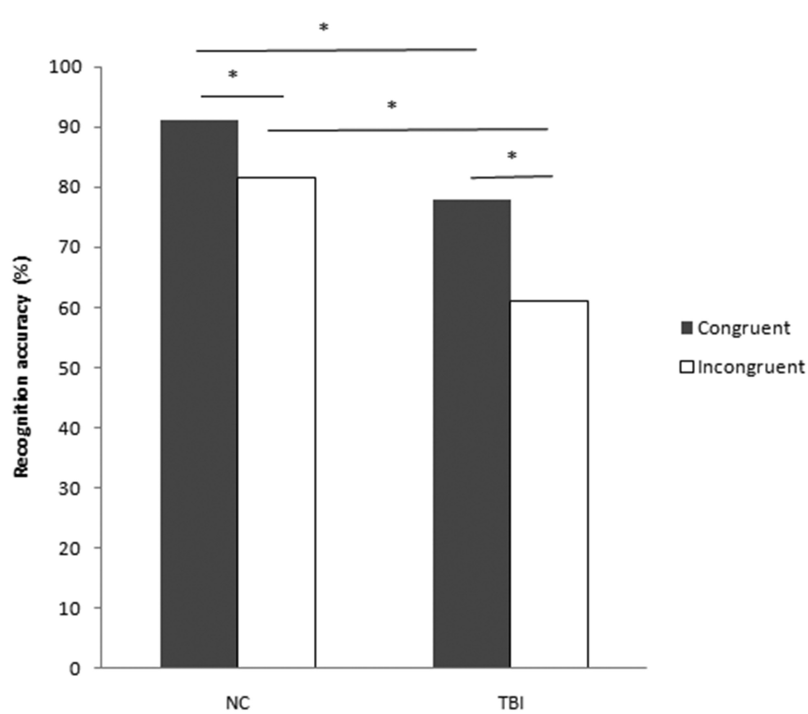

Figure 2. Mean per cent of emotion recognition in TBI and NC groups according to visual context conditions (congruent vs. incongruent).

NC participants and individuals with TBI, Wilcoxon analyses were carried out. The prediction that the congruent condition would improve accuracy for the clinical group was supported (t = 55.5, Z = 4.02, p = 0.00005, r = 0.42). In the same vein, NC adults performed better in the congruent condition than in the incongruent one (t = 219, Z = 3.78, p = 0.0001, r = 0.39).

RT of facial expression recognition

Mean RTs for correct responses in AFECT for groups (TBI, NC) across visual context conditions (congruent, incongruent) are shown in Figure 3. The prediction that individuals with TBI would exhibit longer RTs than NC participants was supported both for congruent condition (U = 261, Z = −5.32, p = 0.000001, r = 0.56) and for incongruent condition (U = 344, Z = −4.99, p = 0.000001, r = 0.53). In addition, both patients with TBI and NC participants took longer time to respond in the incongruent condition than in the congruent condition (for patients with TBI: T = 96; Z = 2.81; p = 0.0049; r = 0.30; for NC participants: T = 292; Z = 4.00; p = 0.00006; r = 0.42).

Relationship between context conditions

To further explore the influence of emotional context on facial expression recognition, we calculated correlations between the two context conditions for each group, separately. Interestingly, Spearman rank correlations demonstrated a significant correlation between congruent condition accuracy and incongruent condition accuracy for NC participants (ρ = 0.41, p < 0.05) but not for individuals with TBI (ρ = 0.16, p > 0.05). Performance on the BTFR did not correlate with accuracy on any of the emotion recognition conditions for either group (all p > 0.05), suggesting that facial expression recognition performance was dissociable from face perception in this sample. Finally, we examined whether demographic variables (age, education level) could account for the underperformance in the incongruent condition. For the group of patients with TBI, there was no significant correlation, neither between AFECT performances and educational level nor between AFECT performances and age of patients (all p-values > 0.05). In contrast, correlation between age of NC participants and incongruent condition accuracy was demonstrated (ρ = −0.52, p < 0.05). No other correlation reached significance (p > 0.05).

Discussion

This study utilized the novel AFECT to investigate how emotional content within visual scenes influenced facial expression recognition for patients having sustained a moderate-to-severe TBI. As predicted, adults with TBI were less accurate and slower at identifying facial expressions of emotion embedded into congruent visual contexts than matched controls and 10 of the 35 adults with TBI were abnormally poor relative to healthy participants. This pattern of results was in line with previous researches relied on emotional faces devoid of context (1,2,8,11,17–33) and illustrated the robustness of the emotion recognition deficit following TBI. However, this impairment did not appear to be attributable to group difference in the ability to recognize faces. Hence, although there was a statistically significant difference in BTFR scores between groups, all the participants performed within the average range on this test (51). Further, there was no correlation between scores on the BTFR and accuracy rates on any of the experimental conditions for either group. Taken together, these data are in line with those reported elsewhere (1,20,53,54) and suggest that facial expression recognition was independent of face perception ability in this sample.

Since our goal was to investigate the influence of visual contextual information on categorization of facial emotions,

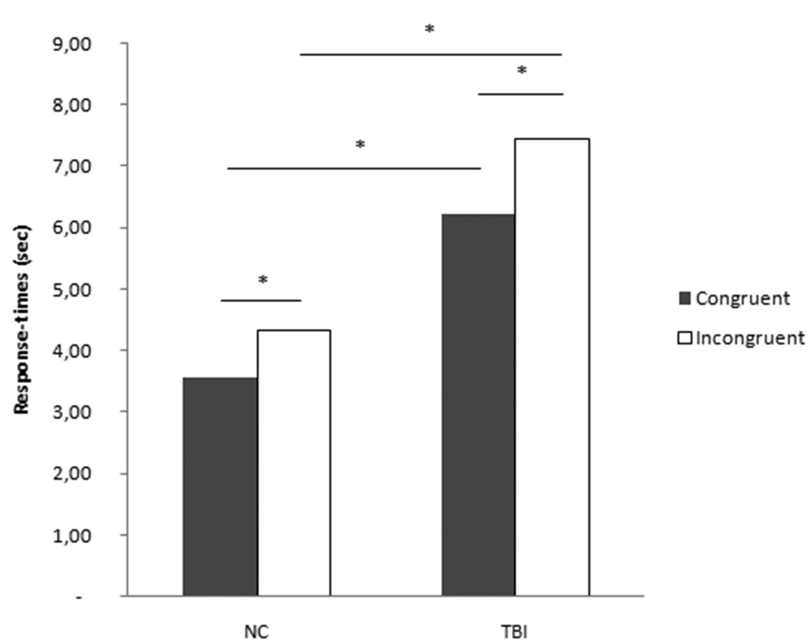

Figure 3. Mean response-times for correct answers (in seconds) in TBI and NC groups according to visual context conditions (congruent vs. incongruent).

we did not examine recognition of emotional faces devoid of context. As a consequence, we cannot determine if the individuals with TBI would improve their accuracy when facial expression is embedded in congruent visual context. Nevertheless, even if they benefited from supportive contextual cues, current results have showed that this would not be to the same degree as NC participants. Thus, consistent with previous literature (20,55,56), current data indicated that having external contextual cues as aids was not sufficient to compensate for the reduced ability in affective perception following TBI and that they still have a disadvantage even with the additional cues. It is possible that patients with TBI need contextual cues that are richer in information than those used in the current research. This hypothesis is underpinned by several lines of evidence that have demonstrated that the addition of body, facial and auditory cues positively contributed to performance of adults with TBI (56,57). In addition, previous researches carried out in patients with progressive neurological diseases (Huntington's disease, behavioural variant of fronto-temporal dementia, semantic dementia) (53,58) did not find any differences in emotion perception accuracy when facial expression was paired with body posture and additional paraphernalia. Body posture context might have advantages over scenes in being processed holistically with faces (59) and integrated automatically (60). Further studies are needed to explore the influence of within-expresser features on facial emotion recognition ability in patients with TBI.

Alternatively, current findings may also suggest that patients with TBI have difficulties in understanding the emotions conveyed by external contextual cues. This is in line with previous investigations that have indicated that patients with TBI experienced difficulty making inferences about emotion (61,62) and mental states in others (e.g. 22,63). Consequently, it might be expected that those with poor social cognition would have more trouble dealing with external visual context. Because we did not propose tasks to solely test participants' ability to recognize the emotion conveyed by context alone, it remains to be known if the disadvantage is due to problems recognizing facial expression, or problems interpreting the context, or both.

As expected, both individuals with TBI and healthy adults obtained lower accuracy scores when a facial emotion was paired with an incongruent visual context than when it was embedded in a congruent visual context. Furthermore, like controls, adults with TBI took longer time to respond when the facial expression was embedded in a contextually incongruent scene. Taken together, these results showed that both groups did notice, and were affected by the misaligned emotional context. Although patients with TBI may detect when the contextual information is inconsistent with the facial expression, they were less efficient than non-brain damaged participants in the incongruent context condition and 6 of the 35 adults with TBI were abnormally poor relative to NC participants. These results are consistent with studies that have indicated that people with TBI have difficulties in understanding complex social situations such as sarcasm (55,64), where external contextual cues are incongruent with nonverbal affect cues.

These results also suggest that difficulties may amplify when the cognitive load and complexity of emotional information expands. Hence, studies with healthy adults have reported that irrelevant context affected categorization of facial emotions (40,42–45,60) and suggested that top-down control may play a role in emotion perception of contextualized facial expressions (42,45,48). Because patients with TBI have been shown to underperform on executive and attention tasks (65), it is possible that our results reflect weaknesses in executive and attentional skills. This possibility is strengthened by the fact that a significant correlation has been observed between the age of healthy participants and accuracy in the incongruent condition, suggesting that older adults were more affected by the incongruent condition than younger participants. These results are consistent with those reported elsewhere (42,43). As no correlation has been shown neither between the age of healthy participants and congruent condition performances nor between the two context conditions both for individuals with TBI and NC participants, perhaps that facial expression recognition in congruent and incongruent conditions is mediated, to some extent, by separate cognitive mechanisms. In line with this hypothesis, Mobbs et al. (48) have pointed out that congruent conditions revealed mainly increased activity in the right amygdala, the temporal pole, the insula as well as in the left hippocampus, whereas incongruent conditions were associated with increased activity in the right ventral prefrontal cortex, the amygdala and the left insula. However, as there is an overlap between the areas of vulnerability in TBIs and cerebral structures implicated in recognition of emotion in context, future studies would be necessary to examine whether specific patterns of deficits may be related to lesion locations.

This study has several limitations that should be considered when interpreting these results. First, all measures administered in the current study used a forced-choice response format that constrained participants to select an emotion. Recently Turkstra et al. (39) have demonstrated by using an open-label format, that both patients with TBI and healthy participants used more social emotion labels when faces were shown in a visual scene. Indeed, patients with TBI labelled more than 70% of items with a word describing social emotions, cognitive state terms or evaluations of the person's attributes rather basic emotions. Unfortunately, no such emotion labels were introduced in current paradigm. Future studies should consider using a forced-choice format that additionally considers both the basic and the social emotions. Second, the current study included an equal number of positive and negative emotions, as experimental control. As a consequence, the overrepresentation of some emotion types did not allow us to investigate the influence of visual external context across emotions and further studies should consider this point. Third, we did not examine affect recognition of faces in isolation and therefore the results did not tell us if participants in either group have improved their accuracy when a facial expression was embedded in a congruent context. Also, ability to recognize the emotion conveyed by context alone was not assessed. Hence, it remains to be known if the impairments could be explained by problems recognizing facial expression or problems interpreting the context or both. This would be of importance in order to better understand how patients perceive others' emotional displays in everyday life.

Finally, alexithymia, that refers to difficulties identifying and describing emotional states in the self as well as in others, that often co-occurs with TBI (66), was not assessed in the current study. Examining alexithymia in patients with TBI would be of interest to determine whether this feature can explain emotion-recognition disabilities in patients with TBI.

Conclusion

There is growing evidence of impairments in affect recognition among adults with TBI, but data are mainly from studies investigating recognition of isolated facial expressions of emotion. Current results highlight the importance of using emotional stimuli that better capture affect processing in real-world contexts to assess emotion recognition in patients with TBI. However, the mechanisms underlying patients' impairments need to be explored in further studies in order to better understand cognitive processes involved in everyday emotion recognition.

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Declaration of interest

Céline Lancelot and Cindy Gilles declare that they have no conflict of interest.

Authors' contribution

CL designed the experiment. CL and CG performed data acquisition and analyses. CL and CG interpreted the results. CL wrote the paper. All authors have contributed to, seen and approved the manuscript.

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